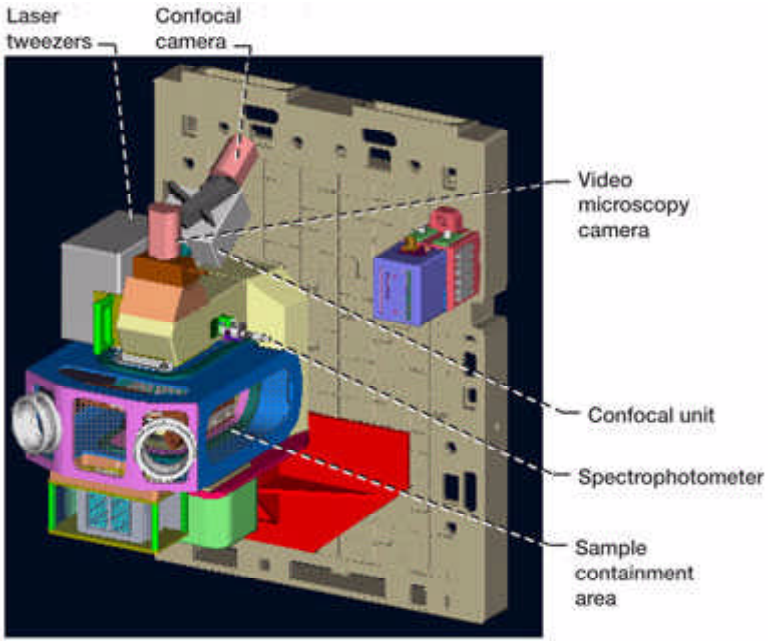
Light Microscopy Module: On-Orbit Microscope Planned for the Fluids Integrated Rack on the International Space Station



The LMM integrated with the FIR optics plate.
Long description Illustration showing laser tweezers, confocal camera, video microscopy camera, confocal unit, spectrophotometer, and sample containment area.

The Light Microscopy Module (LMM) is planned as a remotely controllable, automated, on-orbit facility, allowing flexible scheduling and control of physical science and biological science experiments within the Fluids Integrated Rack (FIR) on the International Space Station. Initially four fluid physics experiments in the FIR will use the LMMthe Constrained Vapor Bubble, the Physics of Hard Spheres Experiment-2, Physics of Colloids in Space-2, and Low Volume Fraction Entropically Driven Colloidal Assembly. The first experiment will investigate heat conductance in microgravity as a function of liquid volume and heat flow rate to determine, in detail, the transport process characteristics in a curved liquid film. The other three experiments will investigate various complementary aspects of the nucleation, growth, structure, and properties of colloidal crystals in microgravity and the effects of micromanipulation upon their properties.

Key diagnostic capabilities of LMM include video microscopy to observe sample features including basic structures and dynamics, thin film interferometry, laser tweezers for colloidal particle manipulation and patterning, confocal microscopy to provide enhanced three-dimensional visualization of colloidal crystal structures, and spectrophotometry to

measure colloidal crystal photonic properties. In addition to using the confocal system, biological experiments will be able to conduct fluorescence imaging by using the fiber-coupled output of the Nd:YAG laser operating at 532-nm, the 437-nm line of a mercury arc, or appropriate narrow-band filtering of the FIR-provided metal halide white-light source.

The LMM will be a modified Leica RXA commercial research imaging light microscope with powerful laser-diagnostic hardware and interfaces, combining to form a one-of-a-kind, state-of-the-art microscopic research facility. It will combine high-resolution color video microscopy with brightfield, darkfield, phase contrast, differential interference contrast, spectrophotometry, and confocal microscopy. An auxiliary fluids container (AFC) will be fastened to the microscope body and sealed to provide a clean working space and one level of containment. Gloveports will allow access to the sample area for cleaning before opening the box and for experiment sample changeout or reconfiguration.

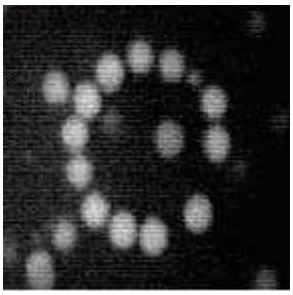
An equipment transfer module (ETM) will transport experiment samples from stowage to the LMM without the risk of contamination release and will be able to be configured to support various experiment modules. It will be located below the AFC, which has a pass-through for the samples. The ETM will be loaded with experiment modules on the ground, providing contained storage until the samples are used in the experiments.

The laser tweezers is a custom-built system with a 1064-nm, 1-W Nd:YAG laser, beam-focusing optics, and two acousto-optic deflectors to steer the trap within the field of view of the microscope. The acousto-optic deflector is a programmable diffraction grating, allowing high-speed scanning of the trap location, which in essence will create multiple trap locations. The tweezer beam will be coupled to the microscope via a lateral port located near the fluorescence turret, and the beam will be deflected into the objective with a dichroic mirror. This mirror will allow simultaneous tweezer and confocal microscope operations. The tweezers will be used both to probe local crystal properties, such as yield stress, as well as to create seed crystals or defects within existing crystals. Thus, they will allow researchers to directly manipulate a colloidal crystal lattice to investigate the viscosity and viscoelasticity of a fluid.

Confocal microscopy will use a 532-nm frequency-doubled Nd:YAG laser, a Yokogawa CSU-10 Nipkow disk confocal unit, and a 12-bit digital charge-coupled device (CCD) camera on a fluorescent-dyed sample. The crystal's three-dimensional structure will be reconstructed by assembling the slices with an image analysis program, from which colloidal growth, structure, and dynamics can be measured.

Spectrophotometry will be used to measure photonic band gaps of colloidal crystals and spectral response of biological samples. This will be done by a monochromator that is attached to the light source, has a spectral bandwidth of less than 10 nm, and is tunable over the entire visible wave-band. The spectrophotometer will take advantage of the optical system within the microscope, in that it will be possible to vary the angle of the incident light on the sample within the range allowable by the numerical aperture of the objective lens.

The project is in the preliminary design phase. During 2001, the team at the NASA Glenn Research Center successfully built an integrated breadboard of the LMM. A preliminary design review will be conducted in late 2001. This work was performed under NASA contract NAS3-99155 by Northrop Grumman Information Technology.



Circular array of 2.3-μm rhodamine-dyed PMMA particles trapped with scanning laser tweezers. Image taken with the confocal unit.

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